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LABORATORY TESTING OF LES MINES SELBAIE ROCK AND FILL

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by

G. Swan*

ABSTRACT

As part of CANMET's rock mass characterization project, understanding the associated element of backfill - rock mass interaction is considered important. The mining of near-surface base metal deposits in Canada and the requirement of stable crown pillars has further emphasized this need. At Les Mines Selbaie, Quebec, mining conditions are considered typical and relevant to a rock mass - backfill/crown pillar interaction study. Results from the preparatory mechanical testing of mine rock core and large scale cemented rockfill are presented.

A feature of the backfill tests was the use of a curing temperature of 6°C. Various admixtures of rock-tailings-cement-cementitous slag were tested to account for the inherent variability of the in situ material.

The rock core was tested for uniaxial compressive strength, deformation modulus, Poisson's ratio, point load index and fracture toughness. The data confirms that no firm distinction exists in the intact rock classification between ore and country rock.

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TESTS DE LABORATORIE ET REMBLAYAGE AUX MINES DE ROCHE SELBAIE

par

G. Swan

RÉSUMÉ

On considère comme partie du projet de caractérisation de la roche de masse au CANMET la compréhension des éléments associés de remblayage. La recherche des dépôts de métal de base près de la surface au Canada et la demande de piliers à couronne stable a souligné davantage ce besoin. Les conditions de l'exploitation des mines aux Mines de roche Selbaie, au Québec sont typiques et relèvent d'une étude sur l'interaction de la couronne du pilier et la masse de la roche. On a présenté des résultats de ces tests mécaniques préparatoires du noyau de la roche et à plus grande échelle le remblayage de la roche au ciment.

Une partie des tests de remblayage était l'usage d'une température de prise à 6°C. Plusieurs mélanges de résidus de roche ciment, scorie cimentaire ont été testé pour mieux expliquer à la variabilité inhérente du matériau sur lieu.

Le noyau de la roche était testé sur la force compressée uniaxial, la déformation du modèle, la proportion de Poisson, la dureté de la fracture et l'index du point de charge. Les données ont confirmé qu'il n'existe pas dans toute la classification de la roche entre les minerais et la roche encaissante.

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INTRODUCTION

Several orebodies are at present being mined in Canada where workings approach close to an unfavourable surface of water, swampy terrain or man-made structures. Given these conditions and a rock mass broadly characterized by heavy jointing, the design of a stable crown pillar is difficult but essential. The recent Belmoral Mine disaster suggested, among other things, that the inclusion of backfill adjacent to the crown pillar area could have contributed greatly to the sub-surface stability and resisted crown pillar cave-in tendencies. Unfortunately no guidelines presently exist from which safe and reliable crown pillar designs can be obtained while meeting the demands of mining economics and maximum extraction.

As part of its efforts to address the rock mechanics of such mining conditions, CANMET has initiated detailed studies to evaluate the supportive qualities of near-surface rock masses. An associated element of this project includes a study of in situ backfill properties (1) together with an assessment of the support function of backfill confinement upon sensitive rock mass structures.

Following a visit by Drs. Hedley and Swan of the Elliot Lake Laboratory in November 1982 to the mine site of Les Mines Selbaie, Joutel, Quebec, a decision was made to commence the evaluation of relevant field data for the above project at this mine. The mine, located about 80 km NW of Joutel, comprises a tabular orebody about 20 m wide by 500 m along strike, dipping at 55°, and extending 180 m below surface. A blasthole stoping method is used and the stopes are filled with cemented rockfill prior to pillar recovery. It is currently planned to mine up dip to achieve a specified crown pillar thickness, tentatively established on 70 m level about 25 m below bedrock. The latter is overlain by glacial till, sand and gravel. Underground, the

hanging wall, orebody and footwall are very blocky and mud zones are present, especially along a fault zone at the footwall contact.

Preparatory to an investigation of the crown pillar stability, research of Selbaie field data is planned to incorporate:

1. testing of backfill and rock material, the former at low temperatures and various gradings;
2. detailed structural geology, especially within the first 70 m where the crown pillar will be established;
3. some basic work on the roughness and stiffness of joints.

The results from element (1) are now reported below.

CEMENTED ROCKFILL TESTS

BACKGROUND

Prior to there being any formal research involvement at Selbaie an arrangement was made to test a number of large scale backfill specimens at the Elliot Lake Laboratory. These specimens were poured into moulds at the mine site and transported by road 900 km to Elliot Lake.

The waste rock (Dacite-Rhyolite) and tailings particle size distributions used are given in Fig. 1. A series of cemented 2:1 rockfill:tailings (CRF) and cemented hydraulic fill (CHF) specimens (designated R1 and H1 respectively) were tested in uniaxial compression. The former specimens (due to sample-maximum particle size recommendations (2)) measured 611 mm diameter x 1180 mm long; the later 145 mm x 290 mm. Omitting details of the testing equipment (see Fig. 3), summarized results are given in Tables 1 and 2 and Fig. 2. A typical failure sequence exhibited by the CRF specimens is illustrated in Fig. 3.

Concerning these preliminary results, various unsatisfactory features

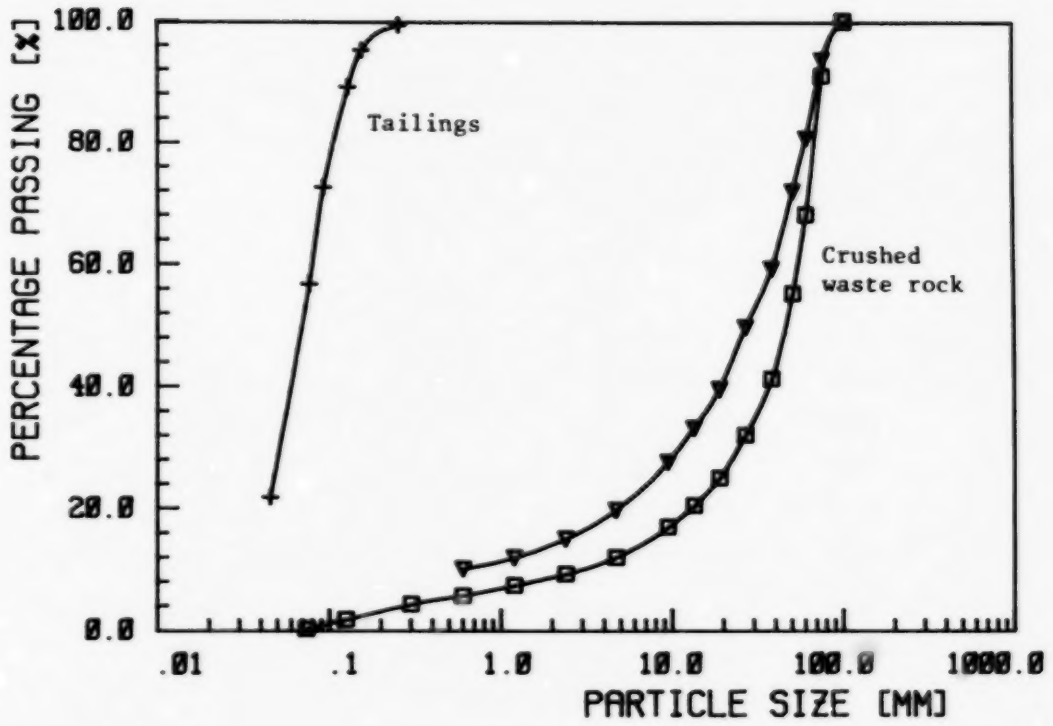


Fig. 1 - Particle size distributions for Selbaie tailings and crushed rock.

Table 1 - Results from preliminary test series R1 on cemented rockfill

Specimen	Mean σ_c (MPa)	Mean E_s (MPa)	Mean ν_p (-)
2007	0.157_3	34.4_2	0.35_1
3007	0.047_3	15.8_3	-
4007	0.063_3	19.1_3	0.32_1
2014	0.113_3	28.9_3	0.16_3
3014	0.053_3	21.8_3	0.27_2
4014	0.070_3	25.4_3	0.30_2
2028	0.103_3	31.3_3	0.16_1
3028	0.160_3	44.1_3	0.32_2
4028	0.123_3	33.3_3	0.40_2

Diameter = 611 mm, length = 1180 mm, density = 2300 kg/m^3

E_s = secant modulus at 50% comp. strength

σ_c = uniaxial comp. strength

ν_p = Poisson's ratio at 90% comp. strength

Subscripts give number of tests.

Table 2 - Results from preliminary test series H1 on cemented hydraulic fill

Specimen	Mean σ_c (MPa)	Mean E_s (MPa)	Mean ν_p (-)
0720	0.26_3	40.2_3	0.01_3
0730	0.12_3	14.7_3	0.19_2
0740	0.13_3	10.3_3	0.12_2
1420	0.38_3	70.3_3	-
1430	0.18_3	31.6_3	0.16_3
1440	0.16_3	36.3_3	0.16_3
2820	0.45_3	68.2_3	-
2830	0.25_3	30.9_3	0.29_3
2840	0.20_3	23.9_3	0.22_3

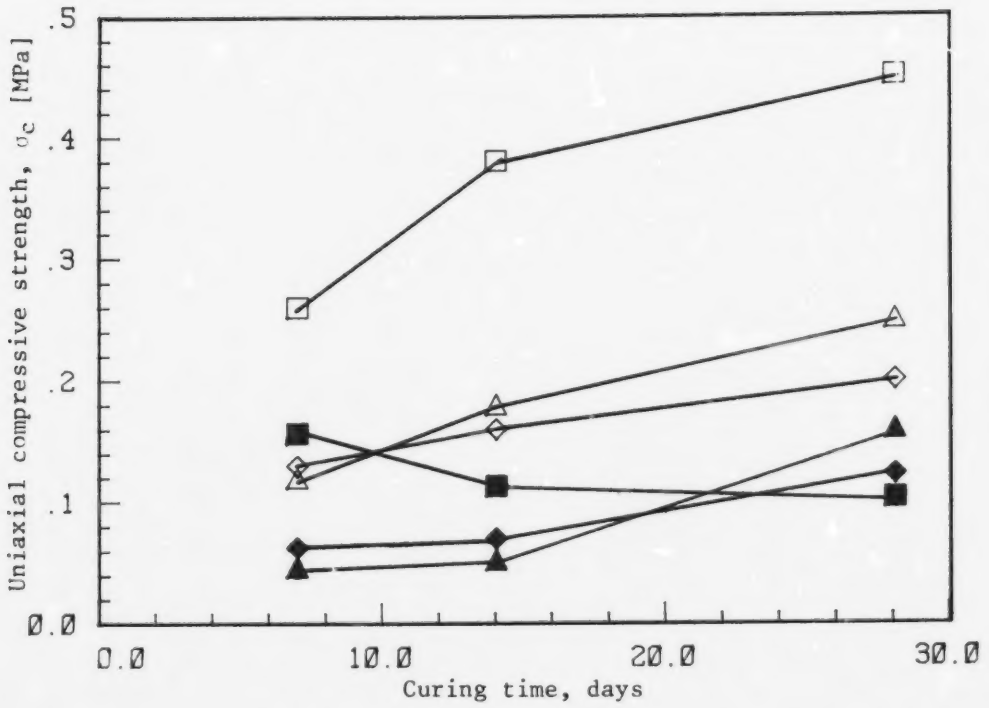
Diameter = 145 mm, length = 290 mm, density = 2005 kg/m^3

E_s = secant modulus at 50% comp. strength

σ_c = uniaxial comp. strength

ν_p = Poisson's ratio at 100% comp. strength

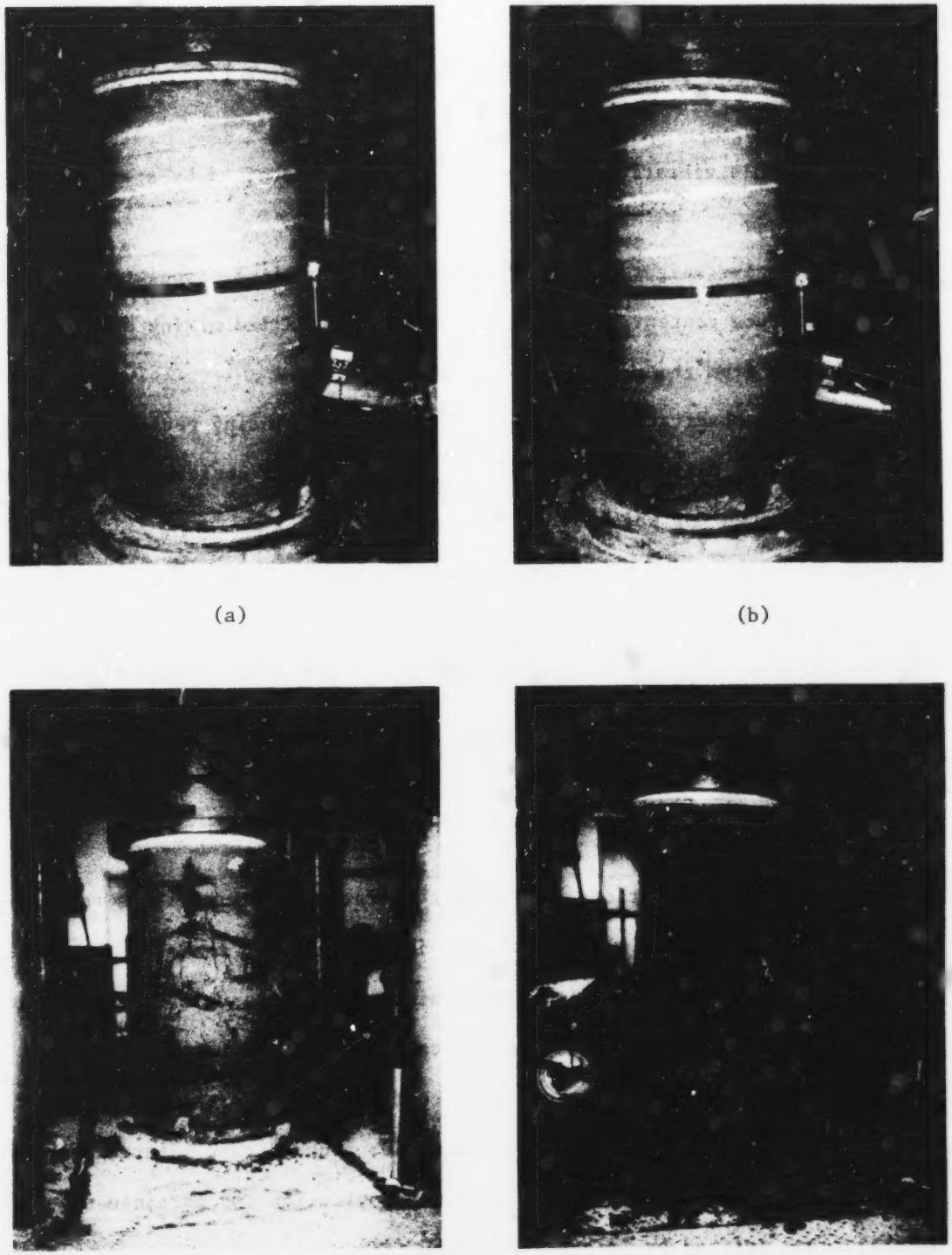
Subscripts give number of tests.



Key

CHF - H1	Volume % Cement in total mix		CRF - R1
□	3.18	1.42	■
△	2.11	0.96	▲
◇	1.59	0.73	◆

Fig. 2 - Uniaxial compressive strength as a function of cure time: test series R1 and H1.



(a) (b)

(c) (d)

Fig. 3 - Large scale CRF test failure sequence. The circumferential displacement gauge was removed at first sign of failure, see (b).

were noted, viz:

a) no curing temperature control was maintained during transportation from mine site;

b) considerable vibrational damage was probably sustained by specimens in transit;

c) the excessive weight of the CRF specimens prohibited associated testing for moisture content, void ratios, etc. No detailed mixing data was available from the pour.

These observations help explain the disappointing performance of the CRF as judged by data from elsewhere (2,3). A further series of tests were therefore planned for which:

a) all specimens would be carefully prepared at Elliot Lake and curing conditions would be maintained at a mine environment temperature of 6°C.

b) nominal size of the CRF specimens would be reduced to 300 mm diameter x 600 mm long. This meant that more than 80% of the particles would still conform to the size requirements.

EXPERIMENTAL DESIGN

Various combinations of curing temperature, rock:tailings ratios, cement and slag contents were considered in the new test series. The final sample set prepared for uniaxial compression testing is summarized in Table 3. Each sample would be mixed individually to ensure ideal control of input parameters and ease of estimating water content and void ratios. For the samples comprising the specimen set 30 and 40, crushed rock material supplied by Les Mines Selbaie would be re-graded to provide for two particle size distributions defined by Talbot's Equation (3):

$$P(u) = 100(u/u_m)^{0.5} \qquad \text{Eq 1}$$

Table 3 - Backfill mix design parameters

Specimen Set-Σ Tested	Rock Fill/ Tailings*	Cement V%Σ	Slag V%Σ	Curing Temp. °C	Curing Period, Days
01-1	2.3	0.87	2.17	20	28
01-2	2.3	0.87	2.17	6	70
02-1	4.0	0.59	1.47	20	28
02-2	4.0	0.59	1.47	6	70
03-1	1.5	1.12	2.79	20	28
03-2	1.5	1.12	2.79	6	70
11-2	2.3	0.44	2.17	6	70
12-2	4.0	0.30	1.47	6	70
13-2	1.5	0.56	2.79	6	70
21-2	2.0	0.88	-	6	70
22-2	3.5	0.60	-	6	70
23-2	1.3	1.13	-	6	70
30-3	Talbot, -100 mm	1.46	-	20	28
40-3	Talbot, -4 mm	5.60	-	20	28

* dry weight ratio.

where u_m, the maximum particle size, would be 100 mm and 4 mm respectively. Both cement and slag quantities are designated by volume percentages since costs ultimately derive from volume rather than weight consumed.

Based upon the mixing conditions chosen, Table 3, in principle, the following observations were possible:

a) influence of low curing temperature upon strength;

b) cement replacement value of slag for a given aggregate and cure temperature;

c) influence of aggregate grading upon strength.

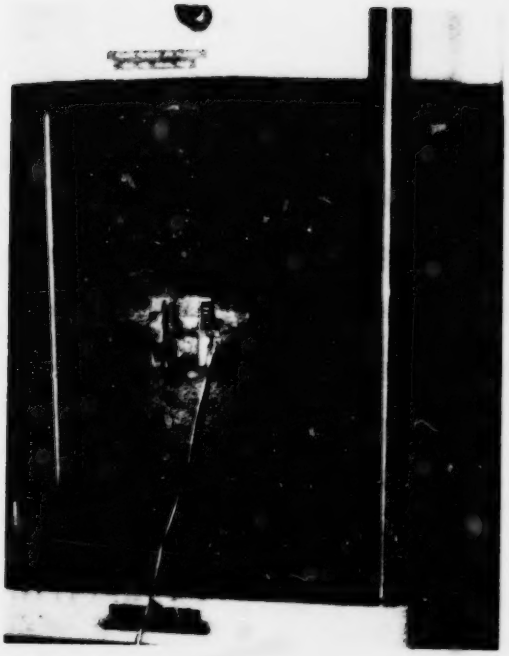
SAMPLE PREPARATION

The backfill specimens were prepared individually, each component being weighed to achieve the mix design according to Table 3. Actual weights are given in Appendix A. Each specimen mould was well perforated to promote good drainage. For each pour, water was introduced separately to ensure saturation conditions (only a minimum of water was added at the mixing stage). As the mix was poured slowly both natural and manual tamping with a rod were used to establish some degree of consolidation. This, it was hoped would realistically simulate the consolidation derived from a full-scale backfill's dead weight.

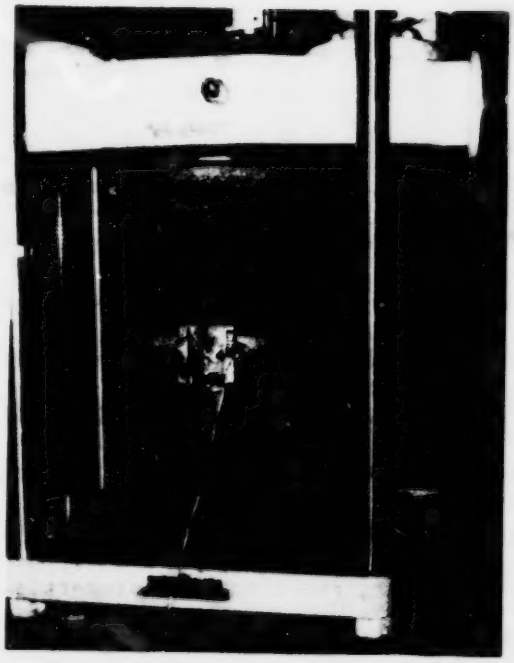
After leaving to drain for several hours, the surface water remaining was decanted and the specimen and its drained water were weighed. Finally, the specimen was sealed in a plastic bag and stored at the design curing temperature.

TESTING PROCEDURE

After curing under design conditions, Table 3, each specimen was re-weighed with and without the moulding enclosure. For those cases where specimens had non-parallel or rough ends, gypsum was used as a filler. When fully prepared, a circumferential displacement gauge was attached, Fig. 4, and



(a) No load.



(b) At failure

Fig. 4 - CRF specimen 02-0 showing circumferential displacement gauge and failed appearance.

the specimen was loaded to failure in a 500 kN press.

TEST RESULTS

The mechanical behaviour of the backfill specimens was evaluated from their stress-strain records, Fig. 5. Radial strain is seen here to be non-existent until the axial stress attains a value approaching 80% of the strength; it then accelerates rapidly. For the expression of Poisson's ratio it was therefore decided to adopt a secant value at 100%
Results for all the specimens are given in Table 4.

Due to their bulk, specimens could not be oven-dried to determine void ratio, etc. Estimates were therefore made knowing the solids densities and the measured mass of water remaining in each specimen prior to its testing. However, since the original mix contained wet components, the total water content was not know precisely. The order of the error is ±10% of the moisture content and the void ratio values. Results are given in Table 5.

DISCUSSION

Based upon the results reported above, a data summary giving mean values is provided in Table 6. Using these data the influence of various parameters upon strength/deformation modulus will now be discussed.

Considering first the influence of cementitious slag addition to cement at curing temperatures of 6°C, Fig. 6 shows normalized strength and deformation modulus for the various rockfill/hydraulic fill ratios tested. To obtain these normalizations it is assumed that for a given fill ratio and over a limited range of cement content, the latter is proportional to the deformation modulus and the strength. The cement replacement value of the slag, X(volume)%, can thereby be estimated by comparison with the cement only control data. For the limited range of specimens tested the replacement value

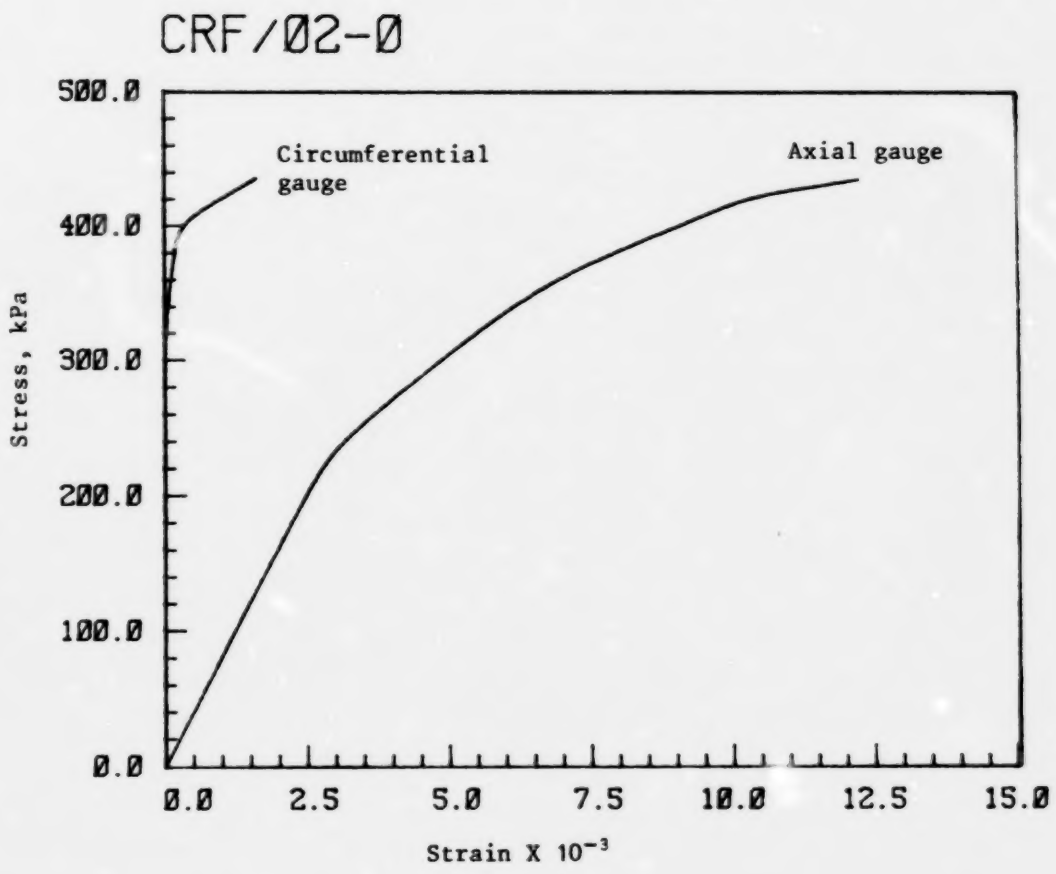


Fig. 5 - Typical stress-strain record of CRF specimens. During pore closure no radial strain can be detected.

Table 4 - Mechanical properties of CRF specimens

Specimen	Uniaxial Comp. Strength, σ_c(MPa)	Deformation Modulus E_{50T}	Deformation Modulus E_{50S}(MPa)	Poisson's Ratio, ν_{100S}(-)
010	0.820	123.9	165.9	0.06
011	0.236	23.5	43.6	0.10
012	0.381	41.8	64.0	>0.29
020	0.435	59.9	80.7	0.12
021	0.211	18.6	27.0	>0.27
022	0.304	60.1	51.5	0.15
030	0.283	77.8	110.1	0.01
031	0.869	116.0	116.0	0.12
032	0.584	69.2	77.3	0.12
111	0.295	24.7	38.9	>0.29
112	0.326	37.9	63.8	0.30
121	0.163	21.4	55.8	>0.40
122	0.130	19.7	26.6	0.42
131	0.433	47.9	63.2	>0.16
132	0.435	81.8	82.0	0.34
211	0.268	28.9	41.4	>0.34
212	0.296	36.4	59.9	0.10
221		SPECIMEN REJECTED		
222	0.152	31.3	35.6	0.21
231	0.310	41.3	59.4	0.13
232	0.324	45.0	66.3	0.17
301	1.200	131.3	131.3	-
302	0.580	181.8	141.4	-
303	0.830	148.0	141.0	-
401	3.333	387.7	-	-
402	3.280	772.5	-	-
403	3.180	770.0	-	-

Table 5 - Physical properties of CRF specimens

Specimen	Bulk Density, ρ (kg/m^3)	Void Ratio, e	Moisture Content, (%)
010	2435	0.26±0.03	10.5±1.0
011	2408	0.28	10.8
012	2359	0.26	7.9
020	2472	0.27	10.6
021	2332	0.41	15.0
022	2379	0.24	5.0
030	2270	0.36	12.8
031	2414	0.23	9.5
032	2364	0.30	12.7
111	2420	0.27	11.1
112	2381	0.24	7.4
121	2364	0.23	3.6
122	2356	0.24	4.4
131	2375	0.20	6.0
132	2353	0.23	6.8
211	2435	0.18	4.8
212	2403	0.24	8.0
211	-	-	-
222	2435	0.20	4.4
231	2341	0.26	9.3
232	2356	0.25	9.3
301	2404	0.25	2.9
302	2290	0.34	4.9
303	2360	0.32	5.8
401	2185	0.47	8.8
402	2213	0.46	9.5
403	2222	0.46	10.1

Table 6 - Summarized CRF test results

Spec. I.D.	Density (kg/m^3)	Void Ratio	Moisture Content (%)	σ_c (MPa)	E_{50T} (MPa)	ν_{100S}
010	2435	0.26	10.5	0.82	123.9	0.06
01	2384	0.27	9.4	0.31	32.7	0.20
020	2472	0.27	10.6	0.44	59.9	0.12
02	2356	0.33	10.0	0.26	39.4	0.21
030	2270	0.36	12.8	0.28	77.8	0.01
03	2389	0.27	11.1	0.73	92.6	0.12
11	2401	0.26	9.3	0.31	31.3	0.30
12	2360	0.24	4.0	0.15	20.6	0.41
13	2364	0.22	6.4	0.43	64.5	0.25
21	2419	0.21	6.4	0.28	32.7	0.22
22	2435	0.20	4.4	0.15	31.3	0.21
23	2349	0.26	9.3	0.32	43.2	0.15
30	2351	0.30	4.5	0.87	153.7	-
40	2207	0.47	9.5	3.26	643.4	-

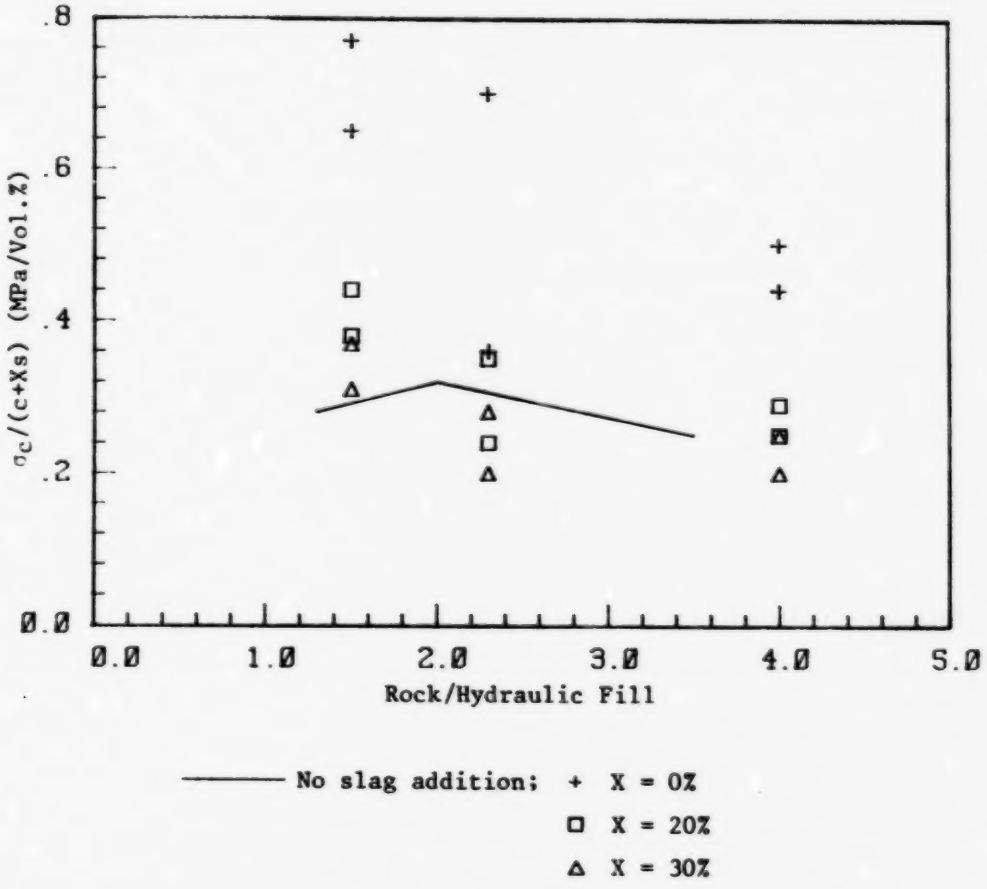


Fig. 6(a) - Normalized CRF uniaxial compressive strength as function of rock/hydraulic fill weight ratio.

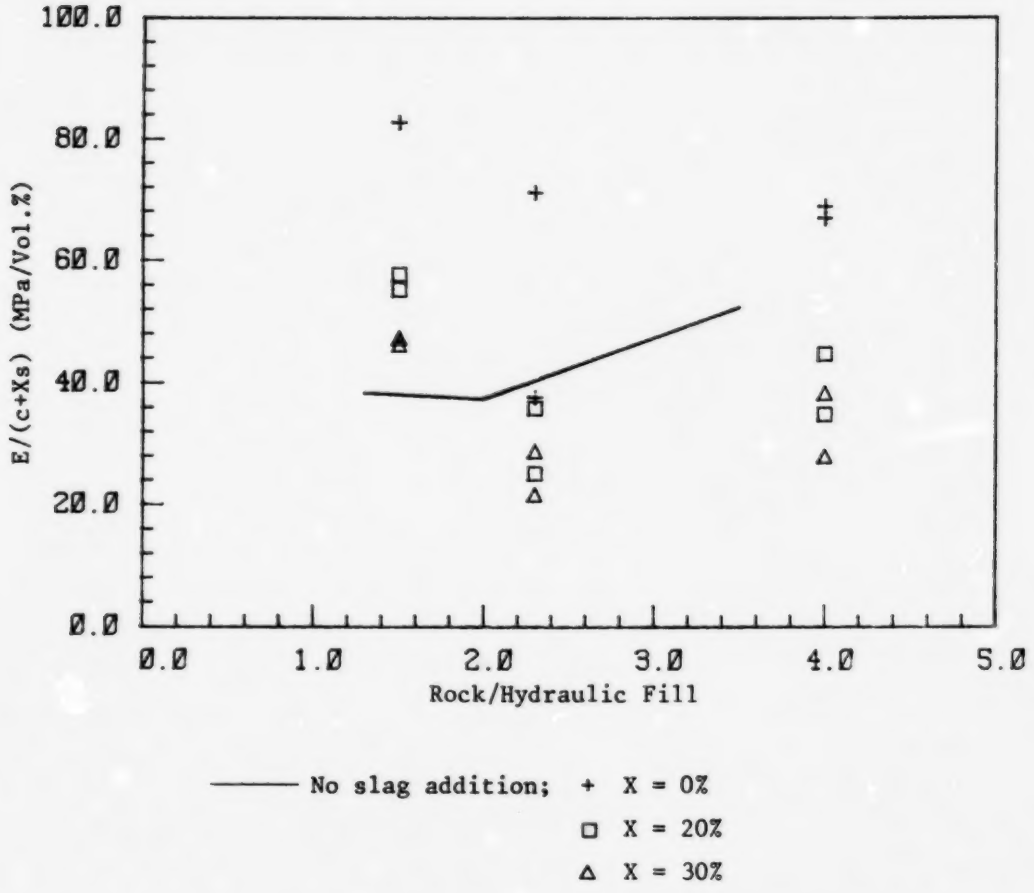


Fig. 6(b) - Normalized CRF deformation modulus as function of rock/hydraulic fill weight ratio.

appears to be only 20-30% that of cement.

Before discussing the influence of grading and temperature it is interesting to compare generally the results with other backfills. While this is not easy, due to the variety of mix/testing parameters used to express any given backfill's quality, a recently devised method (3) offers some hope for an unbiased comparison. Omitting details, the dimensionless parameter $(c/\overline{d}\alpha_p)$* is calculated and plotted against strength (or deformation modulus). This has been done for ten different mine backfills and two standard concretes, Fig. 7. Within the shaded band, backfills are considered optimal for the strength they provide; increasing their cement content results in a shift diagonally, Fig. 7, to the upper right in the shaded band. For points lying above the band, however, grading improvements to the mix are indicated, or curing temperatures/periods may be too low/too short, etc. In the case of the Selbaie data few mixes may be considered optimal and it classifies as a comparatively low-strength backfill.

In order to discuss the Selbaie data quantitatively the various mixes are next plotted separately, Fig. 8. Some, for example, the CRF 30 specimens, are seen to be optimal mixes. The following example will serve to illustrate the relative merits of obtaining such a mix.

Assume a uniaxial compressive strength of 1 MPa is required of the Selbaie backfill. To achieve this, grading, temperature, etc., will remain as for the test data; cement content only will be changed. Using the extrapolated lines shown, Fig. 8, and knowing values of $\overline{d}\alpha_p$ for each mix, the expected cement content can be calculated, Table 7. A cost rating can then be calculated by setting the mix with optimum cement content to unity and adjusting the others in relation to it. As expected, the CRF room temperature/

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* c = cement content, volume %; $\overline{d}$ = aggregate mean free distance; α_p = aggregate specific surface.

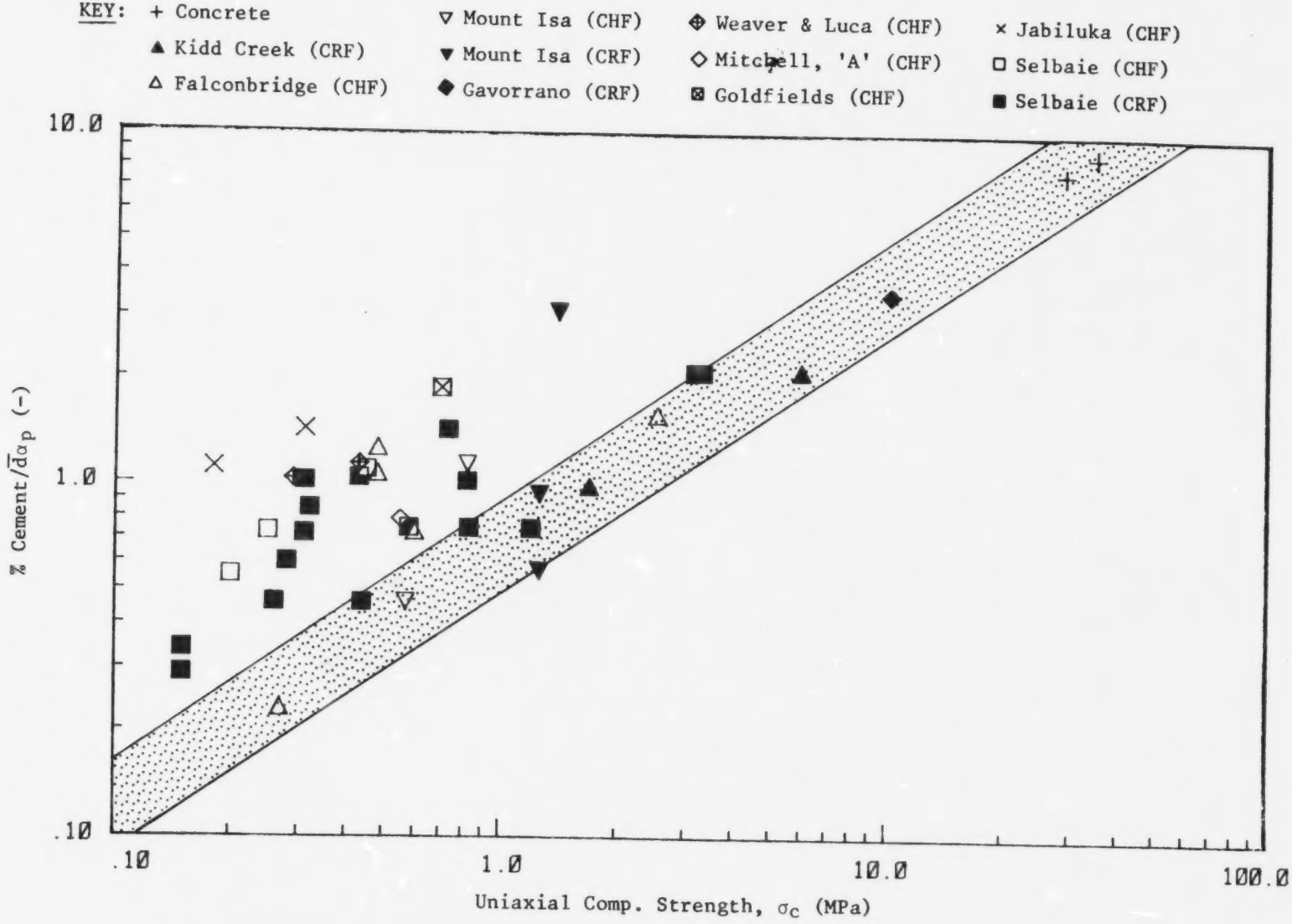

Fig. 7 - Uniaxial compressive strength as function of dimensionless parameter ($c/\bar{d}\alpha_p$). Filled symbols indicate CRF data.

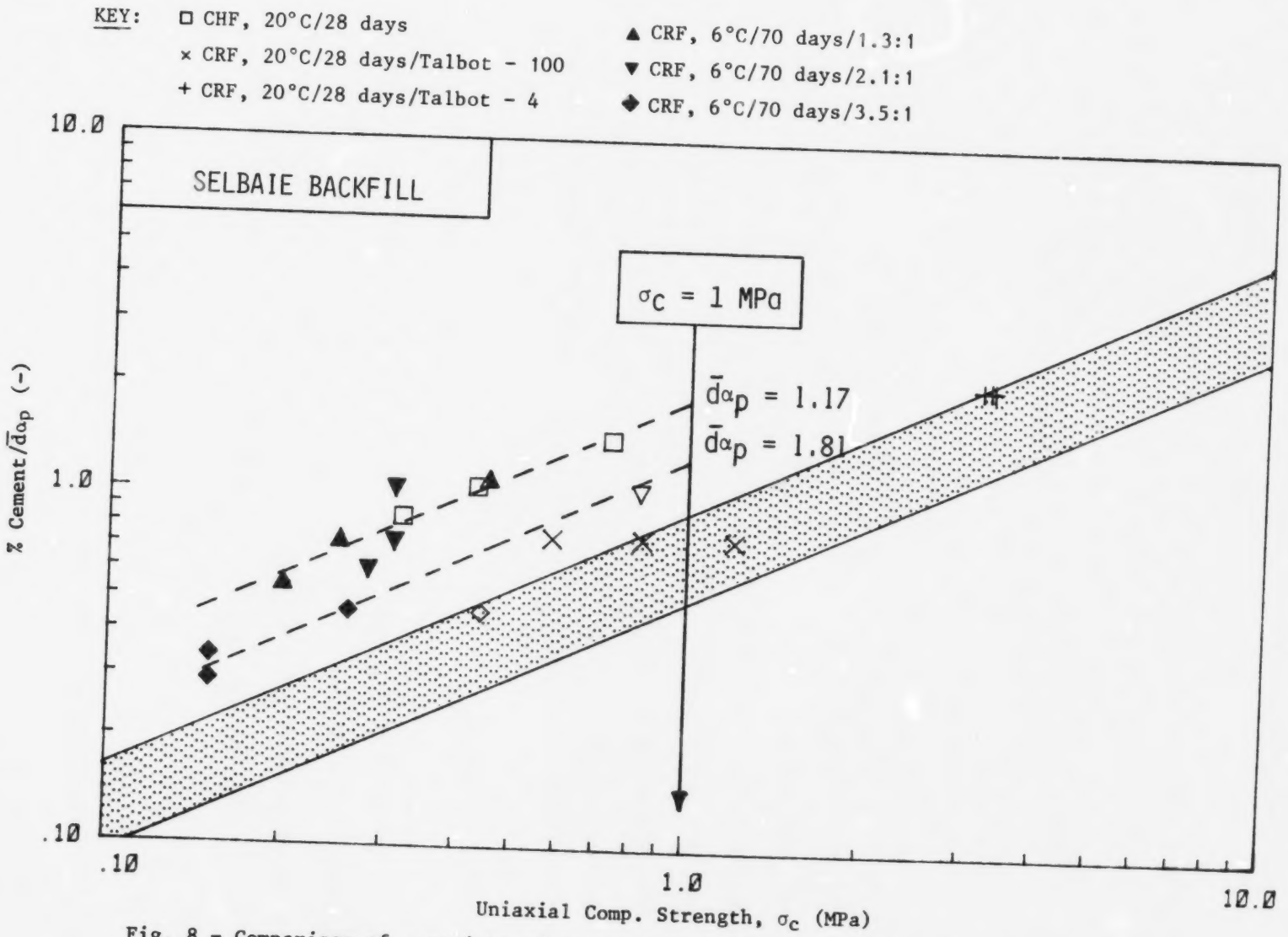

Fig. 8 - Comparison of a variety of tested Selbaie backfills using the $c/\bar{d}\alpha_p$ parameter and strength. Solid symbols indicate curing at 6°C/70 days.

Table 7 - Cement content and cost rating of various Selbaie backfills to provide 1 MPa compressive strength

Type	Vol.% Cement	Cost Rating
CHF, 20°C/28D	5.35	3.82
CRF, 20°C/28D/T-100	1.40	1.00
CRF, 20°C/28D/T-4	2.31	1.65
CRF, 20°C/28D/2.1:1	1.65	1.18
CRF, 20°C/28D/3.5:1	1.45	1.04
CRF, 06°C/70D/1.3:1	2.22	1.59
CRF, 06°C/70D/3.5:1	2.17	1.55

28 day cured Talbot-100 mm (i.e., specimen type 30 above) can be regarded as the optimum backfill. Table 7 also demonstrates:

a) at low curing temperatures regrading a backfill aggregate has a marginal affect upon cement requirements to achieve a given strength;

b) for the same grading, cement requirements are increased by up to 50% as a result of curing at 6°C instead of 20°C;

c) a cemented hydraulic fill will consume up to 382% more cement than an optimized cemented rockfill in providing 1 MPa strength.

MECHANICAL PROPERTIES, ROCK CORE

UNIAXIAL COMPRESSION TESTS

A selection of 36 mm diameter core was made from the 70 m and 120 m level diamond drill logs. The selection attempted to sample the full range of geological material present. Conventional uniaxial compression tests were performed to determine strength, σ_c, and deformation modulus, E_{50T}, using fully strain-gauged specimen. The results are summarized in Table 8. A discussion of these data will be given later.

SHORT ROD FRACTURE TOUGHNESS TESTS

Fracture toughness K_{Ic}, is an intrinsic material property and is a measure of the energy required to create new surface area in intact material. The short rod method of determining toughness is simple and free from scale effects (4). Using a standard configuration (5), K_{Ic} is determined from the equation:

$$K_{Ic} = 25.4\ F_{max}/[D^{3/2}(1 - \nu^2)^{1/2}] \qquad \text{Eq 2}$$

where D is the specimen diameter, ν is Poisson's ratio and F_{max} is the maximum recorded load.

Table 8 - Intact rock core mechanical properties

Specimen Code	σ_c (MPa)	E_{50T} (GPa)	ν_{50T}	Comments
07-02 ;24.1 H/W	159.5	72.8	0.24	Fresh
07-02 ;31.2 H/W	98.2	47.9	-	
07-03 ;59.6 H/W	74.3	26.8	0.26	
07-03 ;66.1 H/W	30.6	21.9	0.25	Alter.
12-121;40.2 H/W	79.5	54.9	-	
12-121;47.2 H/W	67.7	56.6	0.15	
07-02 ; 0.6 F/W	94.8	77.1	0.26	Fresh
07-03 ;10.4 F/W	28.8	50.4	0.43	Weakness p.
07-03 ;16.2 F/W	72.1	17.7	0.20	Alter.
12-111; 5.4 F/W	106.3	74.5	-	Fresh
12-111; 7.6 F/W	112.2	68.7	-	Fresh
12-121;11.8 F/W	73.0	64.3	0.42	
07-02 ;11.5 O/B	56.4	17.9	0.12	Alter.
07-02 ;12.0 O/B	72.5	15.8	0.36	Dacitic
07-03 ;28.5 O/B	41.1	18.6	0.08	Tuff with
07-03 ;53.3 O/B	85.2	27.3	0.35	Weakness p.
12-121;34.7 O/B	133.3	60.7	0.27	High grade

Selecting 36 mm diameter core from 70 and 120 m diamond drill logs as for the compression tests, notched short rod specimens were prepared and tested in a small displacement-controlled press. Results are presented in Table 9.

POINT LOAD TESTS

This strength measure or index method was used to obtain point load index data for the remaining core of the sample selected. Uniaxial compressive strength was calculated using the empirical correlation:

$$\sigma_{ce} = 12\ I_{S(50)} \qquad \text{Eq 3}$$

where, $I_{S(50)}$ is the standardized index. Summarized results are presented in Table 10.

GENERAL DISCUSSION

Taking relevant designs and recommendations from a recent rock mechanics study (6) of Les Mines Selbaie, the newly acquired data can now be used to enhance the discussion of support requirements. At this stage discussion will be limited to a comparative appraisal of data; a subsequent report will discuss support design per se.

Considering first the backfill data, free standing height for 25 m stopes requires a backfill compressive strength of 0.3 MPa (data provided in (6)). For a CRF 3.5:1 (rock/tailings fill) curing at 6°C this will require, according to Fig. 8, 0.9% by total volume of normal Portland cement. On a weight basis this is equivalent to a tailings:cement ratio of 1:22 by weight. At present the mine uses a CRF with 2:1 (rock/tailings fill) and a 1:20 cement:tailings slurry. This is equivalent to 1.46% by total volume cement. From Fig. 8 the strength of this mix will be nearly 0.5 MPa which exceeds design requirements.

Table 9 - Short rod fracture toughness results

Specimen Code	F_{max} (N)	K_{Ic} ($MN/m^{3/2}$)	Comments
07-02 ;24.1 H/W	623	2.41	Fresh Dacite
07-03 ;59.6 H/W	530	2.06	
07-03 ;63.4 H/W	407	1.58	
07-03 ;66.9 H/W	360	1.39	Invalid*
12-111;46.4 H/W	343	1.33	
12-121;42.2 H/W	887	3.36	Fresh
07-02 ; 5.8 F/W	800	3.10	
07-02 ; 5.8 F/W	726	2.81	
07-03 ; 5.2 F/W	773	2.96	Invalid*
07-03 ;15.4 F/W	780	2.98	
12-111; 5.6 F/W	793	3.03	
12-121;23.1 F/W	693	2.65	Invalid*
07-02 ;12.0 O/B	333	1.34	
07-02 ;13.6 O/B	220	0.86	Invalid*
07-02 ;13.6 O/B	323	1.23	Alter.
07-03 ;45.9 O/B	250	0.98	Dacitic
07-03 ;53.3 O/B	380	1.52	Tuff.
12-121;34.1 O/B	660	2.56	High grade

* failed on weakness plane.

Table 10 - Results from point load tests; mean value, no. tests ± standard deviation.

Specimen Code	Index $I_{S(50)}$ (MPa)	σ_{ce} (Eq. 3) (MPa)
07-02 H/W	$6.77_6 \pm 1.21$	$162.6_6 \pm 29.0$
07-03 H/W	$1.74_2 \pm 0.23$	$41.5_2 \pm 4.9$
12-111 H/W	$5.44_2 \pm 2.77$	$130.3_2 \pm 66.3$
12-119 H/W	$3.43_9 \pm 1.86$	$82.6_9 \pm 44.6$
12-127 H/W	$3.62_6 \pm 1.09$	$86.9_6 \pm 26.2$
07-02 F/W	$5.98_2 \pm 1.59$	$143.6_2 \pm 38.4$
12-111 F/W	$7.26_3 \pm 2.56$	$174.7_3 \pm 61.5$
12-119 F/W	$3.40_{14} \pm 1.23$	$81.7_{14} \pm 29.6$
12-127 F/W	$4.72_3 \pm 2.97$	$113.3_3 \pm 41.4$
07-02 O/B	2.82_1	67.8_1
07-03 O/B	$2.12_4 \pm 0.56$	$50.8_4 \pm 13.4$
12-119 O/B	$3.76_{15} \pm 1.22$	$90.2_{15} \pm 29.3$
12-121 O/B	$5.38_2 \pm 0.42$	$129.2_2 \pm 10.3$
12-127 O/B	$4.88_{14} \pm 2.13$	$117.3_{14} \pm 51.2$

Turning to the mechanical properties of the intact rock, the results can be grouped for statistical analysis in various ways. The first choice is usually that of grouping according to mineralized limits along strike, viz., hanging wall/footwall/orebody. For the boreholes sampled this results in the statistics of Table 11. Analysis of the variance indicates that no significant difference exists between the compressive strength, deformation modulus and point load indices of the three zones at the 5% level. The exception, toughness, may be explained on the basis of sample bias due to excessive weathering and alteration to orebody core specimens, i.e., more high grade specimens should have been included in the sample. In any case the data confirm a conclusion made elsewhere (6) that no major distinction to the intact rock classification exists between ore and country rocks for the sections examined (i.e., 2+00N to 3+50N). Moreover, the absolute values for strength and stiffness are in good agreement with those reported previously (6).

Based upon these findings a multi-material computer model with hanging wall/footwall boundaries would seem unnecessary. For modelling local crown pillar behaviour it is clear (6) that joint and fault stiffness properties will be of greater significance to stability than minor variations in the intact rock properties. A detailed appraisal of Les Mines Selbaie modelling for crown pillar stability will be the subject of a later report.

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Table 11 - Statistics of mechanical properties grouped according to longitudinal mineralized zones.

Group	σ_c ±s.d. (MPa)	E_{50T} ±s.d. (GPa)	K_{Ic} ±s.d. ($MN/m^{3/2}$)	$I_{S(50)}$ ±s.d. (MPa)	σ_{ce} ±s.d. (MPa)
Hanging wall	84.9_6	46.8_6	2.15_5	4.30_{25}	103.4_{25}
	±42.7	±19.3	±0.80	±2.15	±51.5
Footwall	78.8_7	58.0_7	2.98_4	4.34_{22}	104.3_{22}
	±24.8	±20.4	±0.12	±2.02	±48.4
Orebody	77.7_5	28.1_5	1.52_5	4.02_{37}	96.5_{37}
	±35.2	±18.8	±0.61	±1.80	±43.2

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APPENDIX A - CRF Mixing Weights

To obtain a sufficient volume of each mix to fill a mould (volume 45×10^{-3} m^3), the relative densities of each component were required. These were taken as:

Rockfill (dry)	2.9
Tailings (wet)	1.8
Tailings (dry)	2.4
Cement	3.1
Slag	2.9

Table A1 - CRF mixing weights

Spec.	Rockfill (kg)	Wet Tailings (kg)	Cement (kg)	Slag (kg)
01	76.9	38.9	1.10	2.58
02	87.9	25.9	0.74	1.72
03	66.0	51.9	1.48	3.44
11	76.9	40.2	0.55	2.58
12	87.9	26.8	0.37	1.72
13	66.0	53.5	0.74	3.44
21	76.9	44.5	1.10	-
22	87.9	29.7	0.74	-
23	66.0	59.3	1.48	-
30	100.0	-	1.65	-
40	10.0	-	0.83	-